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Physics 230

Exam 2

1. A racer attempting to break the land speed record rockets by two markers spaced 100. m apart on the ground in a time of 4.0×10^{-7} s, as measured by an observer on the ground.
   a) What are the two relevant events in this problem?
   b) What is the speed of the racer, as measured by the ground observers? Write this speed as a fraction of c?
   c) How far apart are the two markers according to the racer?
   d) What elapsed time does the racer measure?

2. A racer attempting to break the land speed record rockets by two markers spaced 100. m apart on the ground. He does this in a time of 4.0×10^{-7} s as measured by his watch. Calculate the speed of the racer, as measured by the ground observers? Write this speed as a fraction of c?

3. A hungry lion chases a gazelle. According to observers on the ground, the lion moves to the right at $(4/5)c$ and the gazelle also moves to the right at a speed $(3/5)c$.
   a) How fast, and in what direction, is the lion moving in the rest frame of the gazelle?
   b) How fast, and in what direction, is the gazelle moving in the rest frame of lion?
   Write these speeds as fractions of c.

4. Consider two inertial reference frames S and S', where S' moves in the $+x$ direction at a speed of $(12/13)c$ relative to the S frame. The origins of S and S' coincide at $t = t' = 0$. Later, an event occurs at $x = 75$ m at time $t = 2.0 \times 10^{-6}$ s, as measured by the S frame. What are the spacetime coordinates of this event according to the S' frame?

P1

+63/100

a.) E_1 +25/25

When the racer passes the first marker.

E_2

When the racer passes the second marker.

b.) Rest length of markers is 100 m

time measured by observers is 4.0×10^{-7} s

$D = 100$ m

$t = 4.0 \times 10^{-7}$ s

$V = \frac{D}{t} = \frac{100 \text{ m}}{4.0 \times 10^{-7} \text{ s}} = 2.5 \times 10^{8} \text{ m/s}^2$

/ $D = V \cdot t$

$V = 2.5 \times 10^8$ m/s

$C = 3.0 \times 10^8$ m/s^2

$\frac{V}{C} = \frac{2.5 \times 10^8 \text{ m/s}}{3.0 \times 10^8 \text{ m/s}} = \frac{5}{6} c$

$V = \frac{5}{6} c$

c.) Since $\Delta x' = 0$ $\quad d = D\sqrt{1 - (v/c)^2}$

$\sqrt{\frac{36}{36} - \frac{25}{36}} = \frac{\sqrt{11}}{6}$

$D = 100$ m

$\frac{V}{C} = \left(\frac{5}{6}\right)c$

$\therefore d = 100 \text{ m} \sqrt{1 - \left(\frac{5}{6}\right)^2} = 100 \text{ m} \left(\frac{\sqrt{11}}{6}\right) = 55.2 \text{ m} \approx 55 \text{ m}$

$d = 55$ m

d.) Racecar driver will measure shorter t since moving fast

$t' = \gamma^{-1}(t)$

$\gamma^{-1} = \left(\frac{\sqrt{11}}{6}\right)$

$t = 4.0 \times 10^{-7}$ s

$t' = (4.0 \times 10^{-7} \text{ s})\left(\frac{\sqrt{11}}{6}\right) = 2.21 \times 10^{-7} \text{ s} \approx 2.2 \times 10^{-7}$ s

$\Delta t' = 2.2 \times 10^{-7}$ s

P2 - g

$\Delta t' = 4.0 \times 10^{-7} s$ $D_r = 100m$

$V = \frac{D}{t}$ +4/25

racer will see a contracted distance of

$d = D\sqrt{1 - v^2/c^2} = 100m\left(\frac{\sqrt{11}}{6}\right) = 55m$ depends on v!

he will see his velocity as

$V = \frac{d}{t} = \frac{55m}{4.0 \times 10^{-7}s} = 1.375 \times 10^8 m/s$ +6 ×

$\frac{V}{c} = \frac{1.375 \times 10^8 m/s}{3.0 \times 10^8 m/s} = \left(\frac{11}{24}\right)c$

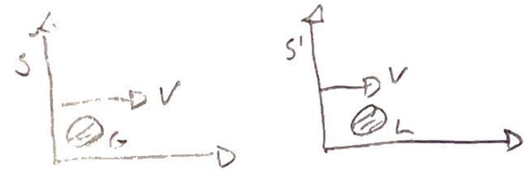
Since the observers are at rest

$V_x' = \left(\frac{11}{24}\right)c$

P3

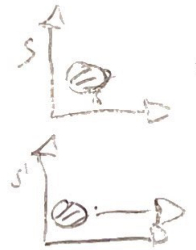
$V_L = (4/5)c \qquad V_G = (3/5)c$

a.) V_L relative to V_G



$V = (3/5)c$ ✗ -2

$V_x' = (4/5)c$ ✓



$$V_x = \frac{V_x' + V}{1 + \frac{V \cdot V_x'}{c^2}} = \frac{(4/5)c + (3/5)c}{1 + \frac{(4/5)c(3/5)c}{c^2}} = \frac{(7/5)c}{1 + \frac{12}{25}} = \frac{(7/5)}{\left(\frac{32}{35}\right)}$$

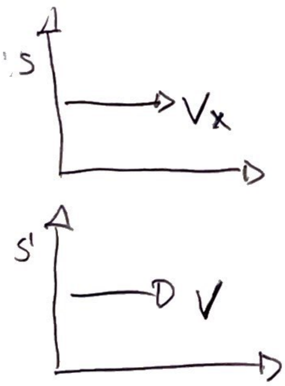
+13/25

$$V_x = \left(\frac{35/25}{37/25}\right) = \left(\frac{35}{37}\right)c$$

$V_x = \left(\frac{35}{37}\right)$ ✗ -3

To right

b.)



$V = (4/5)c$ -2

$V_x = (3/c)c$ ✓

$$V_x' = \frac{V_x + V}{1 + V \cdot V_x / c^2}$$

$$V_x = \frac{(3/5)c + (4/5)c}{1 + \frac{(4/5)c(3/c)c}{c^2}}$$

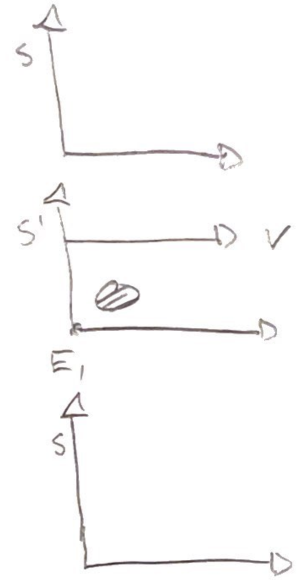
$V_x = \left(\frac{35}{37}\right)c$ ✗ -3

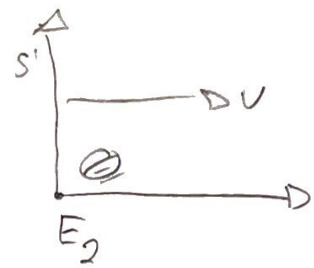
To right ✗ -2

P4

$V = (12/13)c$

+19/25





S' sees both events happen at origin
$\Delta x' = 0$

$t = \gamma(t')$

$t' = \gamma^{-1}(t)$

x_2' & t_2' ?

$v = (12/13)c \quad \gamma = 13/5 \quad \gamma^{-1} = (5/13)$

$x_2 = 75\ m$

$t_2 = 2.0 \times 10^{-6}\ s$

$t' = \gamma(t - vx/c^2)$ ✓

$x' = \gamma(x - vt)$

$$t_2' = 13/5\left(2.0\times10^{-6}s - \frac{(12/13)c(75)m}{c^2}\right)$$

$\frac{900}{13}\ m/c \Rightarrow 2.3\times10^{-7}s$

$$= (13/5)\left(2.0\times10^{-6}s - \frac{900}{13}\ m/c\right)$$

$$t_2' = (13/5)(2.0\times10^{-6}s - 2.3\times10^{-7}s) = 4.6\times10^{-6}s$$ ✓

$t_2' = 4.6\times10^{-6}s$

$x_2' = \gamma(x_2 - vt_2)$ ✓

$x_2 = 75\ m$

$v = (12/13)c$

$t_2 = 2.0\times10^{-6}s$

$\gamma = (13/5)$

$x_2' = (13/5)(75m - (12/13)c(2.0\times10^{-6})s)$

$= (13/5)(75)$

$x_2' = 195\ m$

$$\boxed{\begin{array}{l} t_2' = 4.6\times10^{-6}s \\ x_2' = 195\ m \end{array}}$$ X -6

[illegible]
[illegible]
Phys 270

Exam 3 [illegible]

E1

$+63+\frac{37}{5}=70.4\%$

E2

a.) when the racer (Ed) passes marker 1, when Ed passes marker 2

b.) $D = 100m$

$\Delta t = 4.0\times10^{-7}s$

$V = \frac{D}{\Delta t} = \frac{100\,m}{4.0\times10^{-7}s} = 2.5\times10^{8}\,m/s$

$C = 3.0\times10^{8}\,m/s$ $\quad \frac{V}{C} = \frac{2.5\times10^{8}\,m/s}{3.0\times10^{8}\,m/s} = \frac{5}{6}$

$V = \left(\frac{5}{6}\right)c$

c.) Since $\Delta x' = 0$

$d = D\cdot\sqrt{1-(V/c)^2} = 100m\sqrt{1-(5/6)^2} = 100m\left(\sqrt{\frac{11}{36}}\right) = 100m\left(\frac{\sqrt{11}}{6}\right) = 55\,m$

$D = 100m$

$d = 55m$

d.) Since $\Delta x' = 0$ $\quad t = \gamma(t') \therefore t' = t\gamma^{-1}$

$t = 4.0\times10^{-7}s$

$\gamma' = \frac{\sqrt{11}}{6}$

$\gamma = \frac{6\sqrt{11}}{11}$

$\Delta t' = \frac{\sqrt{11}}{6}\left(4.0\times10^{-7}s\right) = 2.2\times10^{-7}s$

$\Delta t' = 2.2\times10^{-7}s$

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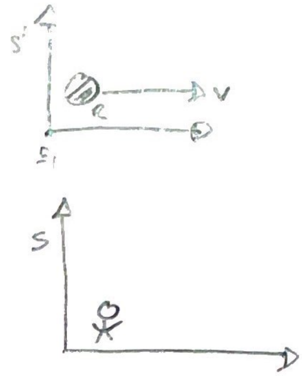
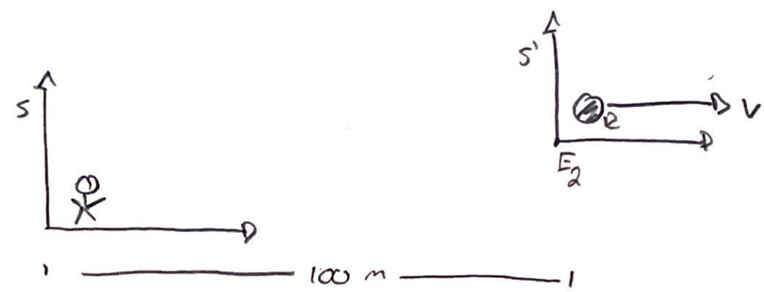
Exam 2 Problem 6

$\underline{E_1}$



+19

$\underline{E_2}$



$\Delta x = 100\ m$
$\Delta t' = 4.0 \times 10^{-7} s$

$\Delta x' = 0$

∞ observers in S' $\therefore \Delta t' = 0$ ✗ $\therefore\ x = \gamma x'\ \therefore\ x' = \gamma^{-1}(x)$

$$x = \gamma(+vt')$$

$$\Delta x = \frac{v(\Delta t')}{\sqrt{1-(v/c)^2}}$$

$$\Delta x\left(\sqrt{1-(v/c)^2}\right) = v(\Delta t') \checkmark$$

$$(\Delta x)^2\left(1-(v/c)^2\right) = v^2(\Delta t')^2 \checkmark$$

$$\Delta x^2 - \Delta x^2(v/c)^2 = v^2(\Delta t')^2 \checkmark$$

$$\Delta x^2 = v^2(\Delta t')^2 + \Delta x^2(v/c)^2 \checkmark$$

$$\frac{\Delta x^2}{c^2} = \frac{v^2}{c^2}\Delta t'^2 + \Delta x^2\frac{v^2}{c^4} \checkmark$$

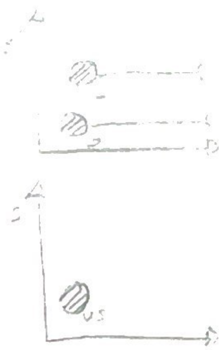
$$\frac{\Delta x^2}{c^2} = \frac{v^2}{c^2}\left(\Delta t'^2 + \frac{\Delta x^2}{c^2}\right) \checkmark$$

$$\frac{v^2}{c^2} = \frac{\frac{\Delta x^2}{c^2}}{\Delta t'^2 + \frac{\Delta x^2}{c^2}} \checkmark$$

$$\frac{v}{c} = \sqrt{\frac{\Delta x^2}{c^2\Delta t'^2 + \Delta x^2}} \checkmark$$

$$\frac{v}{c} = \sqrt{\frac{(100\ m)^2}{(3.00\times10^8)\ m/s\,(4.0\times10^{-7})\ s + (100 m)^2}}$$

$$\frac{v}{c} = 0.64c \checkmark$$



$$V_x = \frac{V_x' + V}{1 + V V_x'/c^2}$$

$$V_x' = \frac{V_x - V}{1 - V \cdot V_x/c^2}$$

$V_L = (4/5)c \quad V_G = (3/5)c$

+12

a.) RF of Gazelle . . .

$V = (3/5)c$

$V_x = (4/5)c$

$$V_x' = \frac{(4/5)c - (3/5)c}{1 - \frac{(4/5)c(3/5)c}{c^2}} = \frac{(1/5)c}{13/25} = \frac{5/25}{13/25} = \frac{5}{13}$$

$V_x' = \left(\frac{5}{13}\right)c$

Rightward

✓

b.) RF of Lion . . .

$V = (4/5)c$

$V_x = (3/5)c$

$$V_x' = \frac{(3/5)c - (4/5)c}{1 - \frac{(4/5)c(3/5)c}{c^2}} = \frac{-(1/5)c}{\left(\frac{13}{25}\right)} = \frac{-\left(\frac{5}{25}\right)c}{\left(\frac{13}{25}\right)} = \left(-\frac{5}{13}\right)c$$

$V_x' = \left(\frac{-5}{13}\right)c$

Leftward

✓

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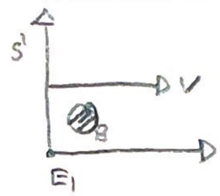
Exam 2 Problem [illegible]

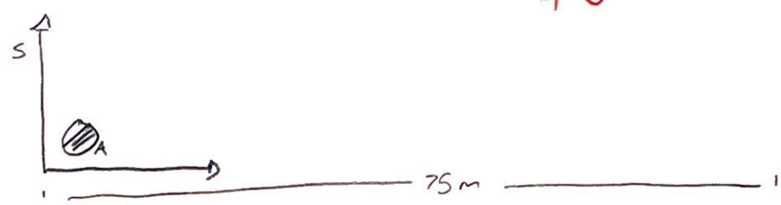
$\underline{E_1}$

$V = (12/13)c$



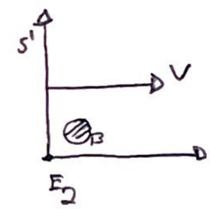
+6

$\underline{E_2}$



$x_1 = 0 \quad t_1 = 0 \quad x_2 = 75\,m \quad t_2 = 2.0\times10^{-6}s$

$x_1' = 0 \quad t_1' = 0 \quad x_2' = \quad t_2' = 4.6\times10^{-6}s$



$V = (12/13)c \qquad \gamma = \left(\frac{13}{5}\right)$

$t' = \gamma(t - Vx/c^2) \qquad t = \gamma(t + Vx/c^2)$

$x' = \gamma(x - vt) \qquad x = \gamma(x' + vt)$

$$t_2' = \left(\frac{13}{5}\right)\left(2.0\times10^{-6}s - \frac{(12/13)c(75)m}{c^2}\right)$$
$$= \left(\frac{13}{5}\right)\left(2.0\times10^{-6}s - \frac{900}{13}m/c\right)$$
$$= \left(\frac{13}{5}\right)(1.769\times10^{-6}s)$$
$$t_2' = 4.6\times10^{-6}s$$

$$x_2' = \left(\frac{13}{5}\right)\left(75\,m - \left(\frac{12}{13}\right)c(2.0\times10^{-6}s)\right)$$
$$= \left(\frac{13}{5}\right)(75\,m - 1.84\times10^{-6}c\,s)$$
$$= \left(\frac{13}{5}\right)(75\,m - 554\,m)$$
$$x_2' = -1245.4\,m$$

$$\boxed{\begin{aligned} t_2' &= 4.6\times10^{-6}s \\ x_2' &= -1200\,m \end{aligned}}$$

✓